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Evaluation of AMIP-2 Snow Cover Simulations

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We present results from fifteen AMIP-2 simulations (table 1) whose simulations of snow covered area (SCA) and snow water equivalent (SWE) are being evaluated. Frei and Robinson (1998) evaluated SCA simulations from twenty-seven AMIP-1 GCMs, finding that at continental to hemispheric scales there were biases in the mean annual snow cycle, including underestimated fall and winter SCA over North America and overestimated spring SCA over Eurasia. The models also failed to reproduce observed interannual variability of SCA.

The principal data set used for estimating historical large-scale SCA is based primarily on visible-band satellite imagery. This weekly data set, produced by the National Oceanic and Atmospheric Administration (NOAA), covers the period from 1967 to present (see climate.rutgers.edu/snowcover). In addition, for AMIP-2 simulations, two new data sets based on combinations of station observations and snow pack models are used to evaluate simulated SWE over North America. Brown et al. (2002) have developed a gridded dataset of SWE over North America specifically for use in evaluating AMIP-2 models. Approximately 8000 snow depth observations per day, obtained from US and Canadian stations, are used in an iterative spatial interpolation routine along with a snow pack model to estimate SWE values on a lat-lon grid of approximately 0.3° resolution. We focus on the region south of 55N, as few stations are located farther north. Grundstein et al. (2002) have developed a 1°x1° gridded SWE data set over the northern Great Plains of the US. Their data set was developed using more sophisticated snow pack modeling, but less sophisticated spatial interpolation, compared to the Brown et al data set. In addition, we use the gridded temperature and precipitation data set of Willmott and Matsuura (2001) to identify causes of regional snow cover biases.

<u>Northern Hemisphere SCA</u> The seasonal biases identified in AMIP-1 models are no longer apparent in AMIP-2 (Frei et al. 2002). Figure 1 shows boxplots of monthly mean SCA over Northern Hemisphere lands from fifteen AMIP-2 models along with observed values (asterisks). Figure 2 (left panel) shows mean winter (DJF) SCA values from observations and from each

model. Models are generally within 5% of observed values. Also shown in figure 2 (right panel) are simulated and observed ranges of winter SCA values. AMIP-2 models tend to underestimate variability in SCA, but less severely than AMIP-1 models.

ACRONYM	RESEARCH INSTITUTE	LAT/LON GRID
1 **CCCMA**	Canadian Centre for Climate Modelling and Analysis	3.8 x 3.8
2 **CCSR**	Center for Climate System Research	2.8 x 2.8
3 **CNRM**	Centre National de Recherches Meteorologiques	2.8 x 2.8
4 **DNM**	Department of Numerical Mathematics	3.9 x 5.0
5 **ECMWF**	European Centre for Med-Range Weather Forecasts	2.0 x 2.0
6 **GLA**	Goddard Laboratory for Atmospheres	3.9 x 5.0
7 **JMA**	Japanese Meteorological Agency	1.9 x 1.9
8 **MRI**	Meteorological Research Institute	2.8 x 2.8
9 **NCAR**	National Center for Atmospheric Research	2.8 x 2.8
10 **PNNL**	Pacific Northwest National Laboratory	2.8 x 2.8
11 **SUNYA**	SUNY, Albany	2.8 x 2.8
12 **UGAMP**	The UK Universities' Global Atm Mod Programme	2.5 x 3.8
13 **UIUC**	University of Illinois at Urbana-Champaign	3.9 x 5.0
14 **UKMO**	United Kingdom Meteorological Office	2.5 x 3.8
15 **YONU**	Yonsei University	3.9 x 5.0

Table 1. Models included in this analysis of AMIP2 snow simulations.

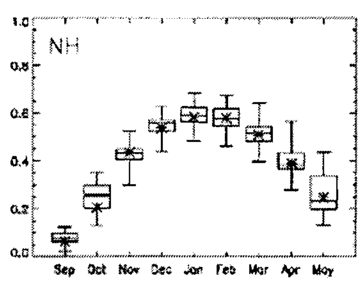

Figure 1. Observed and modeled monthly mean SCA over the Northern Hemisphere. Box and whiskers show results from 15 AMIP-2 models; asterisks indicate observed values. SCA is expressed in fraction of land area north of 20N.

Consistent biases in SCA over large regions (>15 degrees longitude) are prevalent near the southern boundary of the winter snow pack over Eurasia. The region with the largest bias is eastern Asia, including the Tibetan Plateau and eastern China, where models overestimate SCA by $>10^6$ km^2 in January. Over western Asia (30-60E) models understimate SCA, but the magnitude of the bias is approximately half of the bias over eastern Asia. Figure 3 illustrates the bias in one representative model. While these biases in SCA are consistent with model biases in temperature and precipitation when compared to Willmott and Matsuura (2001), there is little correlation between the magnitude of temperature or precipitation biases and the magnitude of

SCA biases. Over North America models also have biases, but for large regions (>15 degrees longitude) they are not consistent between models.

<u>North American SWE and SCA</u> Over smaller regions we do find consistent biases over North America. Over the northern Great Plains of the US the models tend to underestimate SWE and overestimate SCA (figure 4). The models tend to deposit a snow pack that is more shallow, but spatially more extensive, than observations indicate. The overestimation of SCA is particularly apparent in winter and spring.

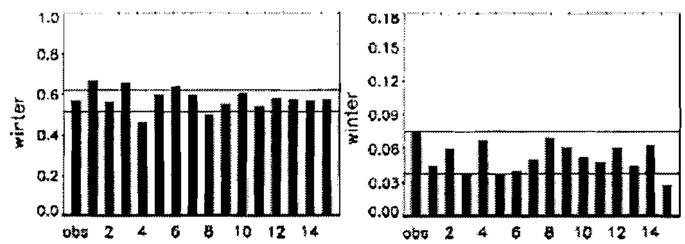

Figure 2. Observed and simulated mean (left panel) and range (right panel) of winter SCA over Northern Hemisphere lands. SCA is expressed in fraction of land area north of 20N.

Over the northern Great Plains models are not capturing the magnitude of large SWE events that are occasionally experienced in this region. As cold air masses tend to dominate, a deep snow pack will persist subsequent to large events, resulting in large monthly SWE values compared to the median. This occurs in almost half of the observed Januaries during the AMIP-2 time domain. Modeled SWE in this region is much less variable (figure 4).

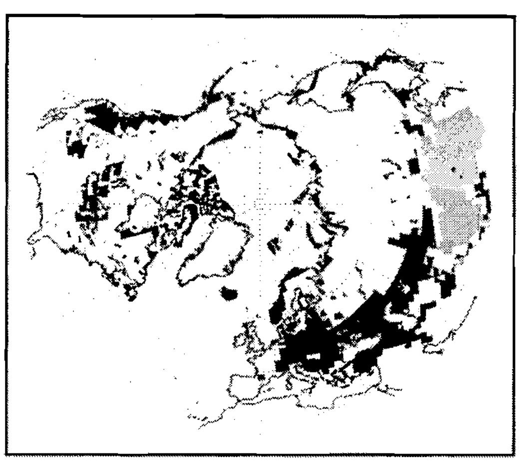

Figure 3. Spatial distribution of bias in mean winter SCA for the MRI AMIP-2 model. Regions of model underestimation >25% are shown in black; model overestimation >25% shown in gray. SCA is expressed in fraction of land area north of 20N.

The underestimation of SWE is not isolated to one small region. Over North America as a whole there is a tendency for models to underestimate SWE. The largest, as well as the most consistent, biases are found over the Pacific coast where orographically induced precipitation associated with maritime air masses result in deep snow packs. All models underestimate SWE in this region.

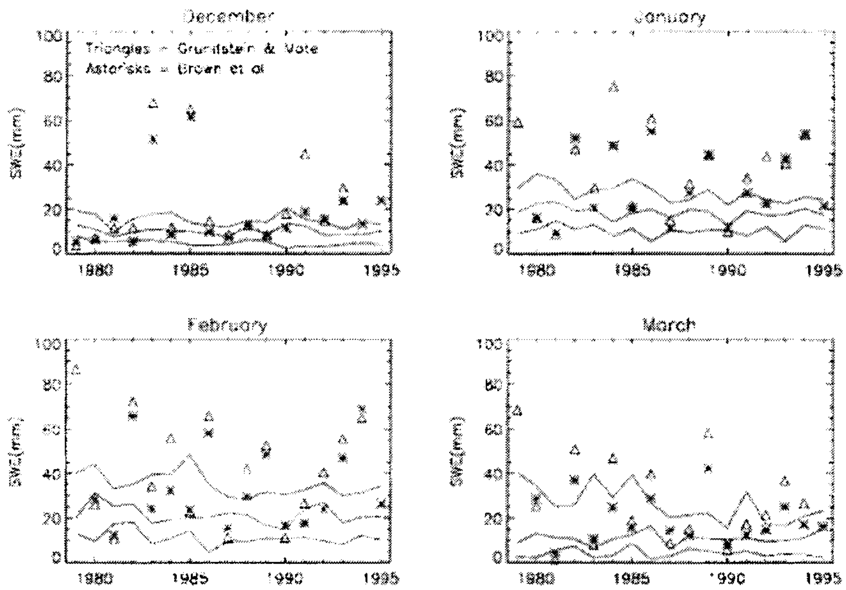

Figure 4. Northern US Great Plains monthly mean SWE (mm) for observed values (asterisks and triangles) and AMIP-2 models. Solid lines indicate bottom quartile, median, and upper quartile of the 15 AMIP-2 models.

References

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